Next-Generation Ecosystem Experiments (NGEE Arctic): Biogeochemical and Geophysical Characterization of Permafrost Ecosystems on the North Slope of Alaska

Peter Thornton

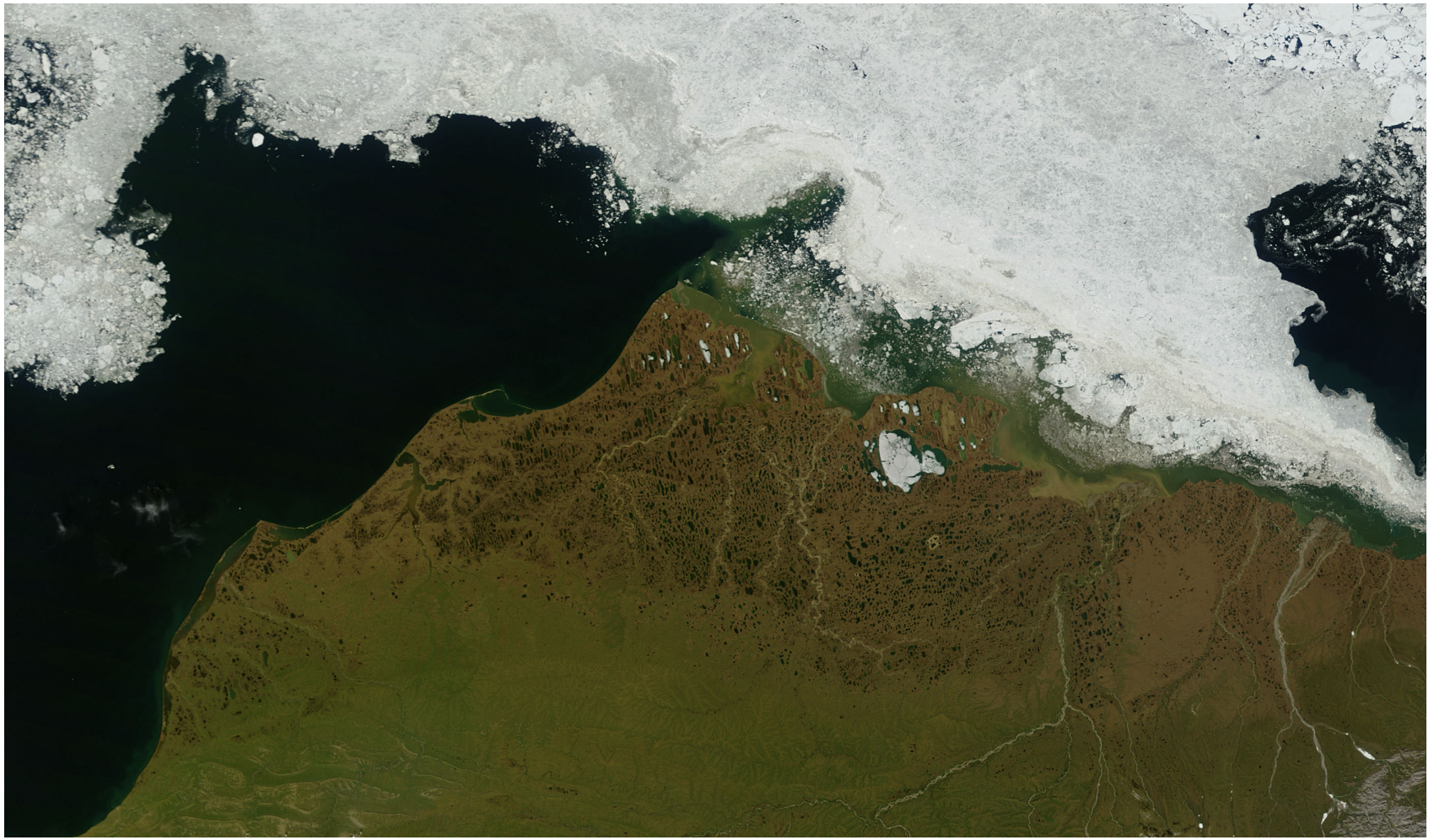
Representing the NGEE Arctic Science Team

NGEE Arctic: Goal

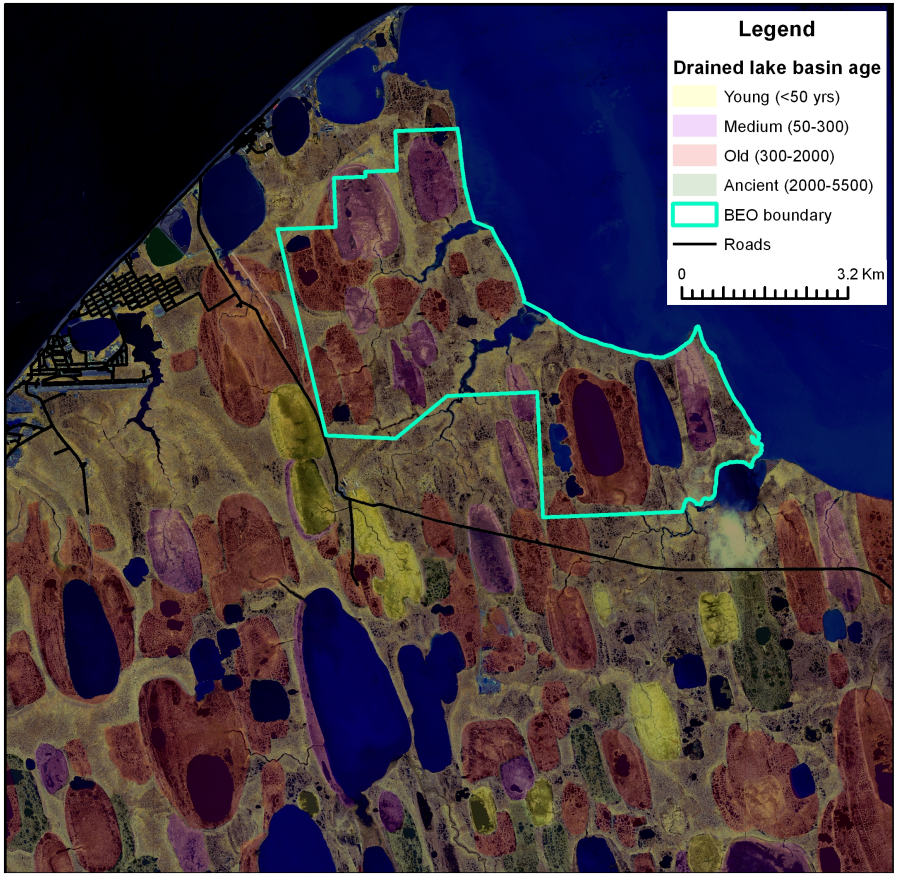
Deliver a *process-rich ecosystem model, extending from bedrock to the top of the vegetative canopy, in which the evolution of Arctic ecosystems in a changing climate can be modeled at the scale of a high resolution Earth System Model grid cell (i.e., 30x30 km grid size).*

Science themes:

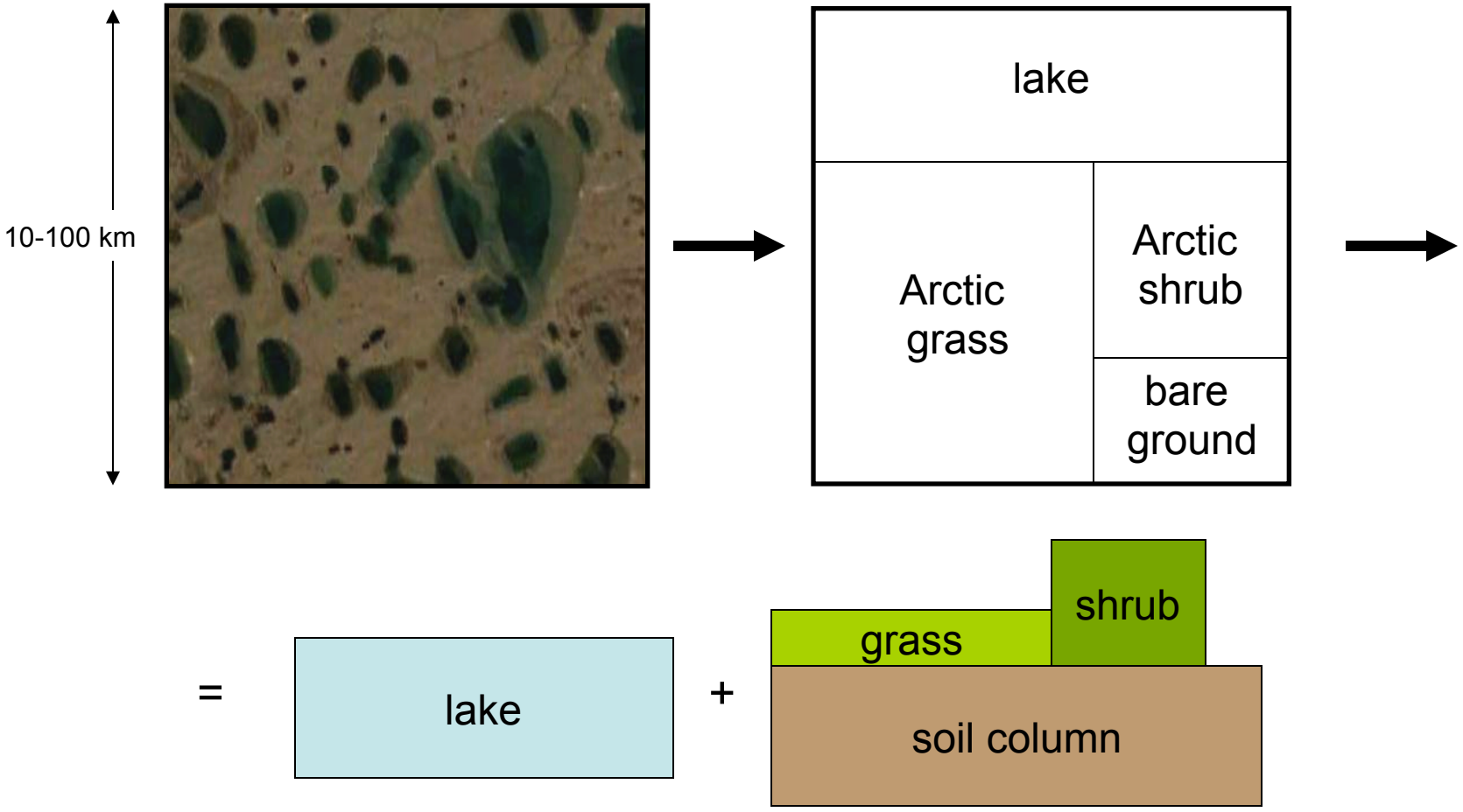
- **Geomorphology** (e.g., surface-subsurface interactions)
- **Hydrology** (e.g., vertical and lateral)
- **Biogeochemistry** (e.g., CN, CO_2 and CH_4)
- **Vegetation dynamics** (e.g., plant functional types)
- **Energy** (e.g., permafrost dynamics, albedo)
- **Modeling** (e.g., multi-scale representation of Arctic landscapes)



Alaska Coastal Plain


Legend
Drained lake basin age
Young (<50 yrs)
Medium (50-300)
Old (300-2000)
Ancient (2000-5500)
BEO boundary
Roads
0
3.2 Km

Current scaling approach for land component of climate prediction model (e.g. CLM4)

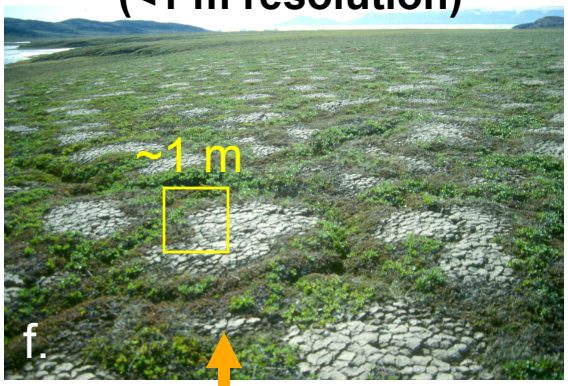


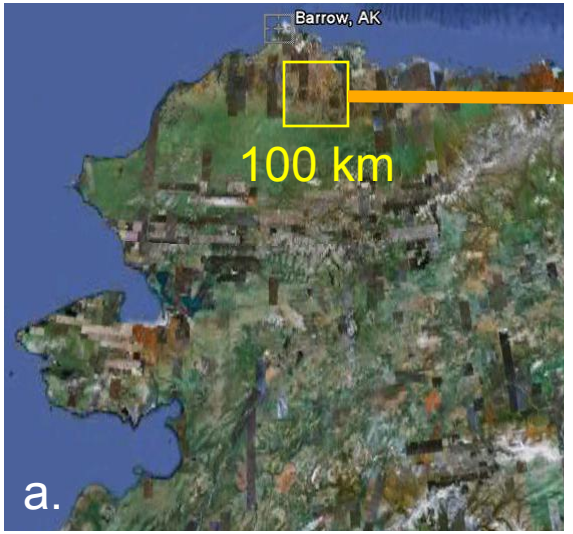
Best ESMs currently use quasi one dimensional approach, with assumption of linear scaling

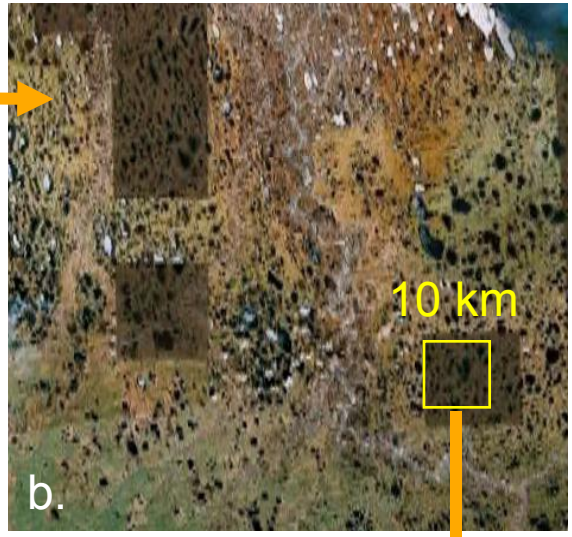
Hypothesis: Linear scaling not a good assumption in Arctic tundra landscapes under warming scenario

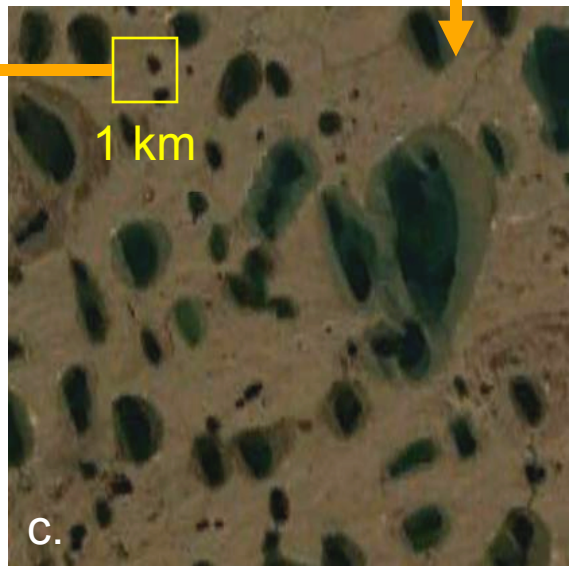
Typical GCM / ESM scales (1°x1°) ≈ 100km

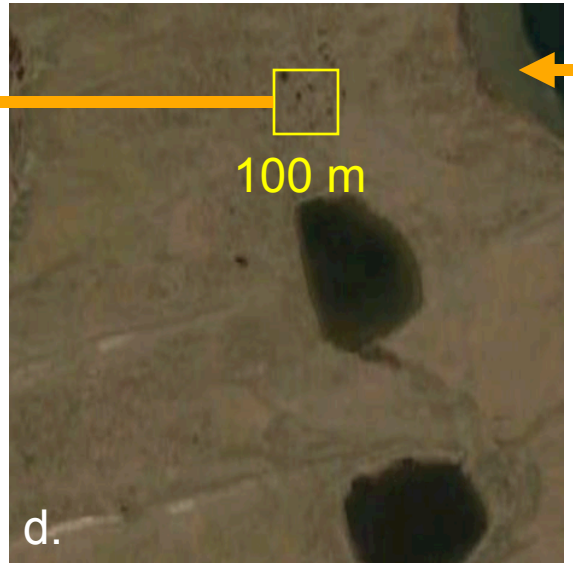
Site scale (<1 m resolution)

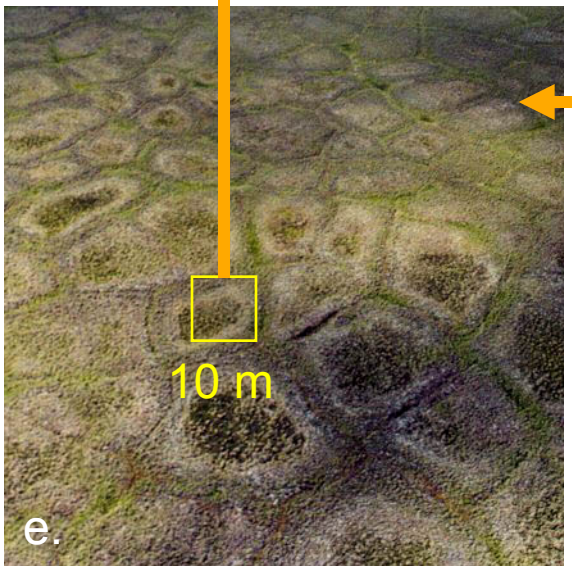






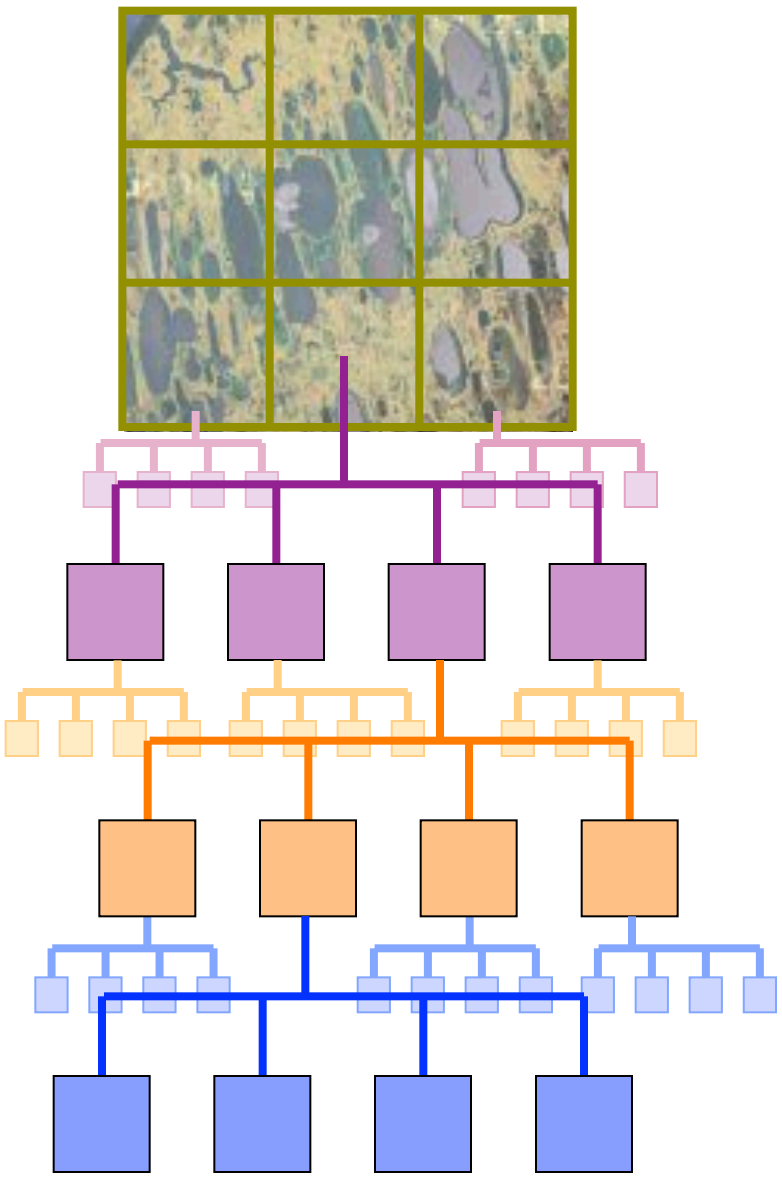






Landscape scales (100 m to 10 km)

NGEE-Arctic implementation of CLM4 subgrid hierarchy



Gridcells: This is the level at which land surface states and fluxes, such as albedo and net carbon exchange, are coupled to the atmosphere component of CESM.

Landunits: Each landunit is defined as a hydrologic basin, with explicit geographic location and extent within its parent gridcell. Basin delineation based on high-resolution DEM.

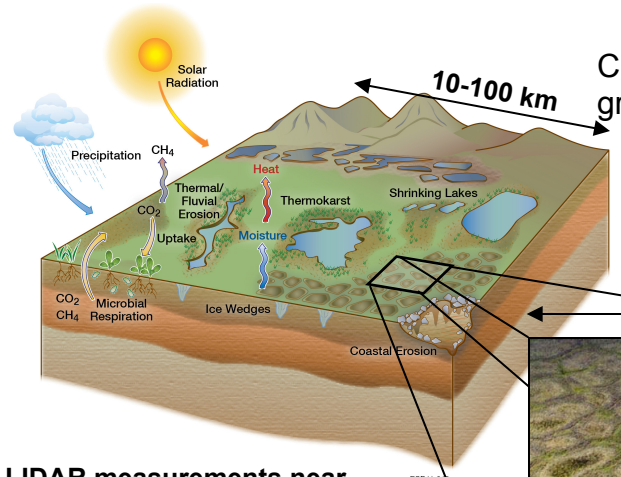
Soil Columns: Geomorphologically distinct land types are represented as separate soil columns.

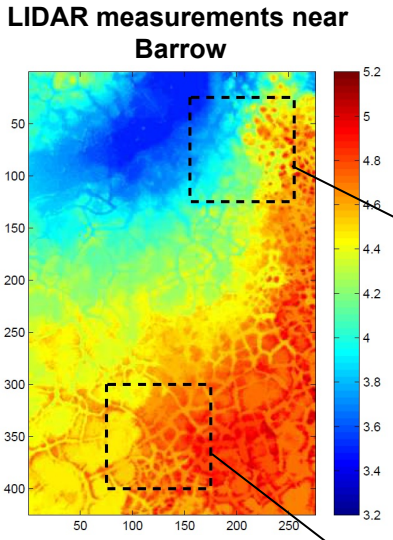
Plant Functional Types: Each soil column can be occupied by multiple interacting vegetation types, as well as a fraction of bare ground.

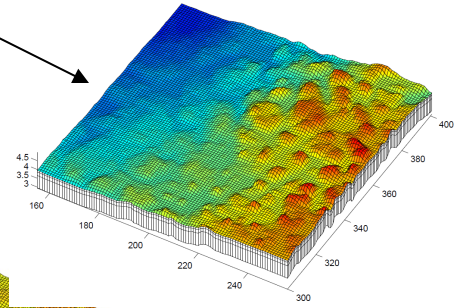
3-D process-resolving Arctic tundra landscape simulator

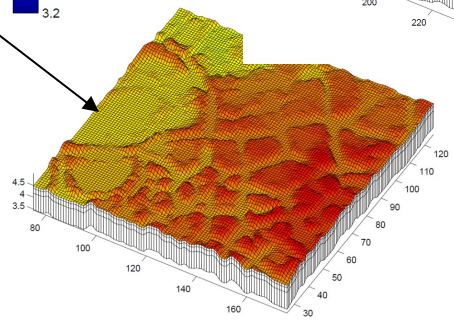
Process requirements

- Subsurface
  - Permafrost
  - Differential ice concentrations
  - Active layer thickness
  - Biogeochemistry
- Surface
  - Deformable topography
  - Surface flow and flow paths
  - Snowpack dynamics
  - Vegetation dynamics
- Near-surface atmosphere
  - Canopy and topographic interactions on turbulence, snow dynamics, and gas-exchange



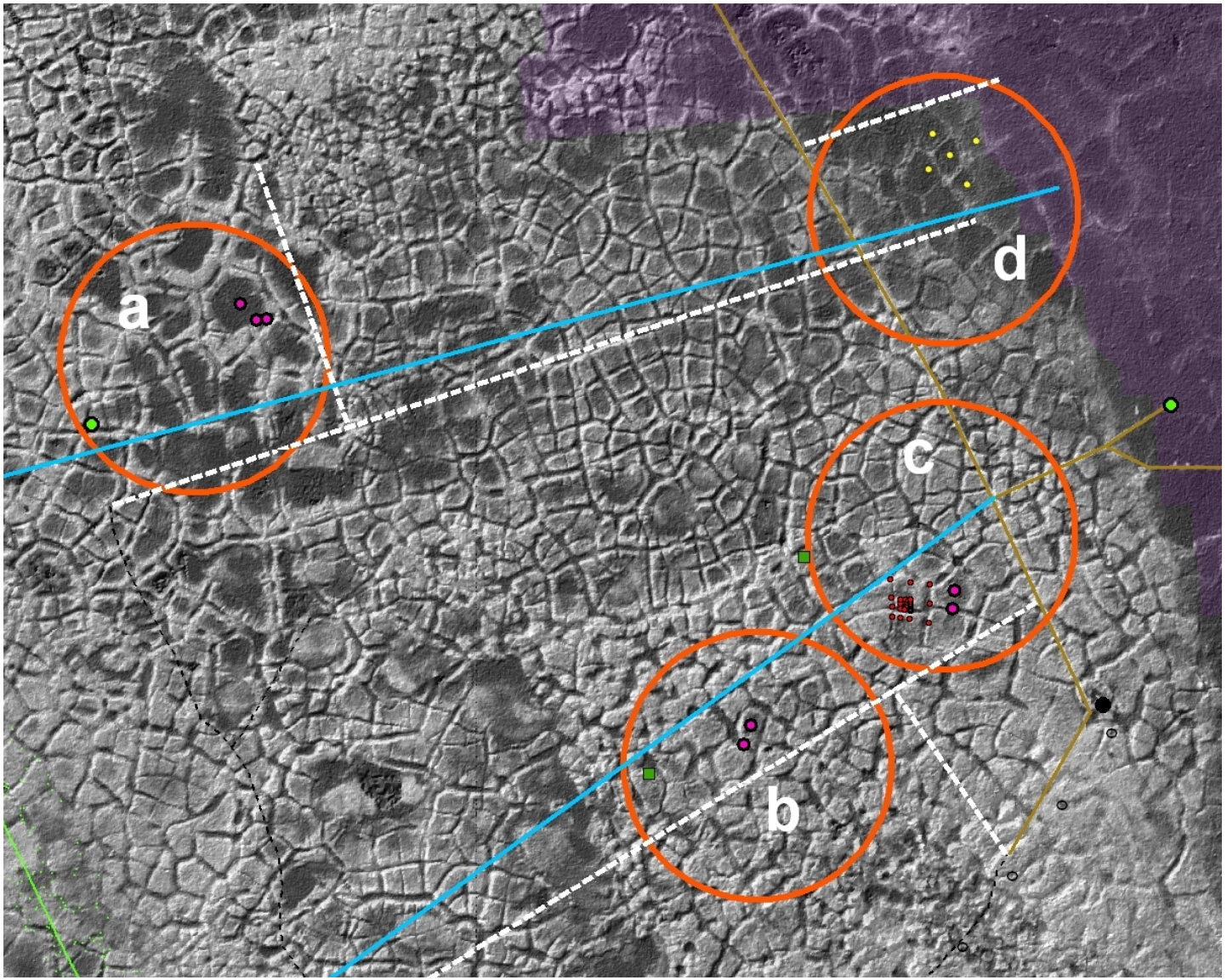


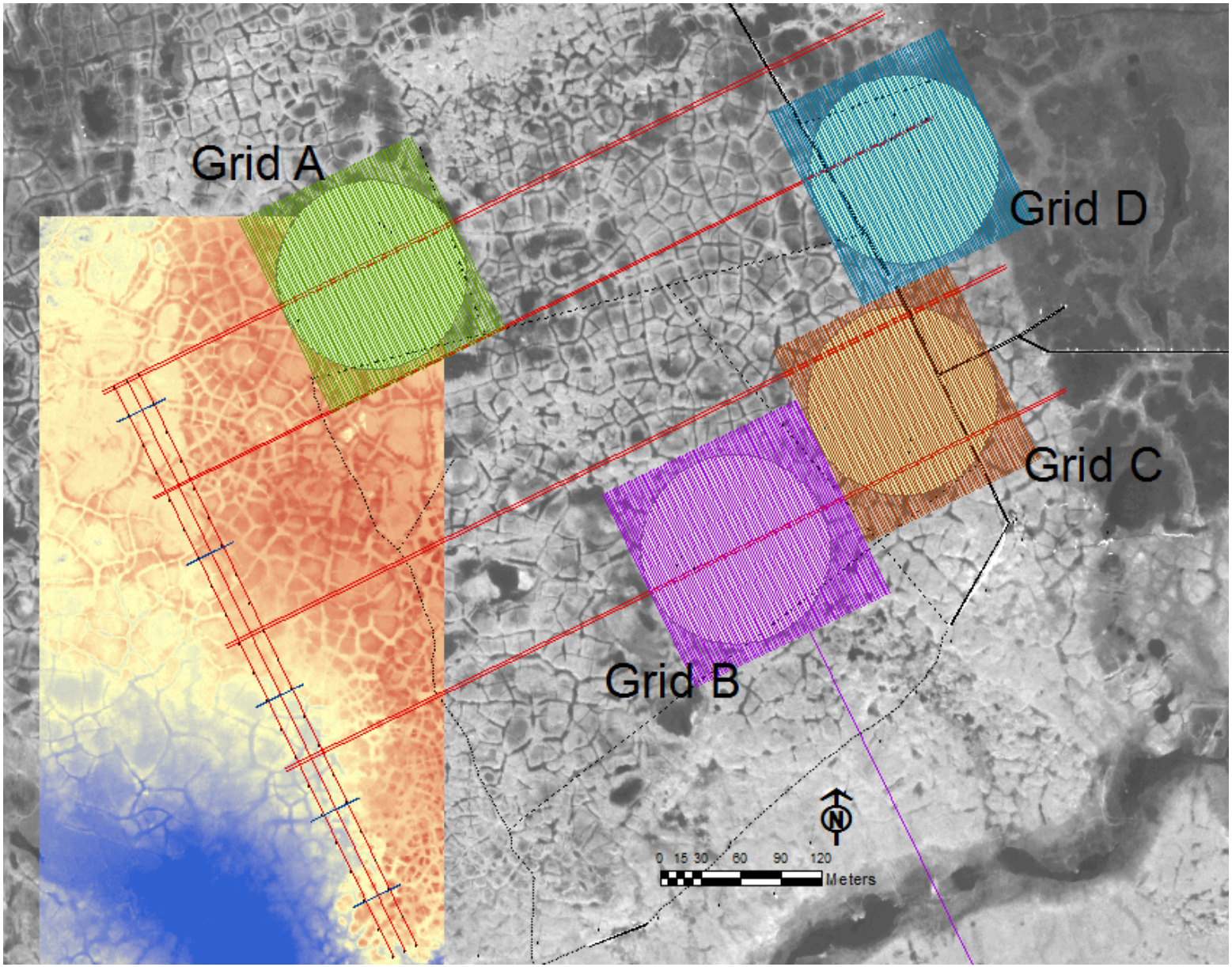




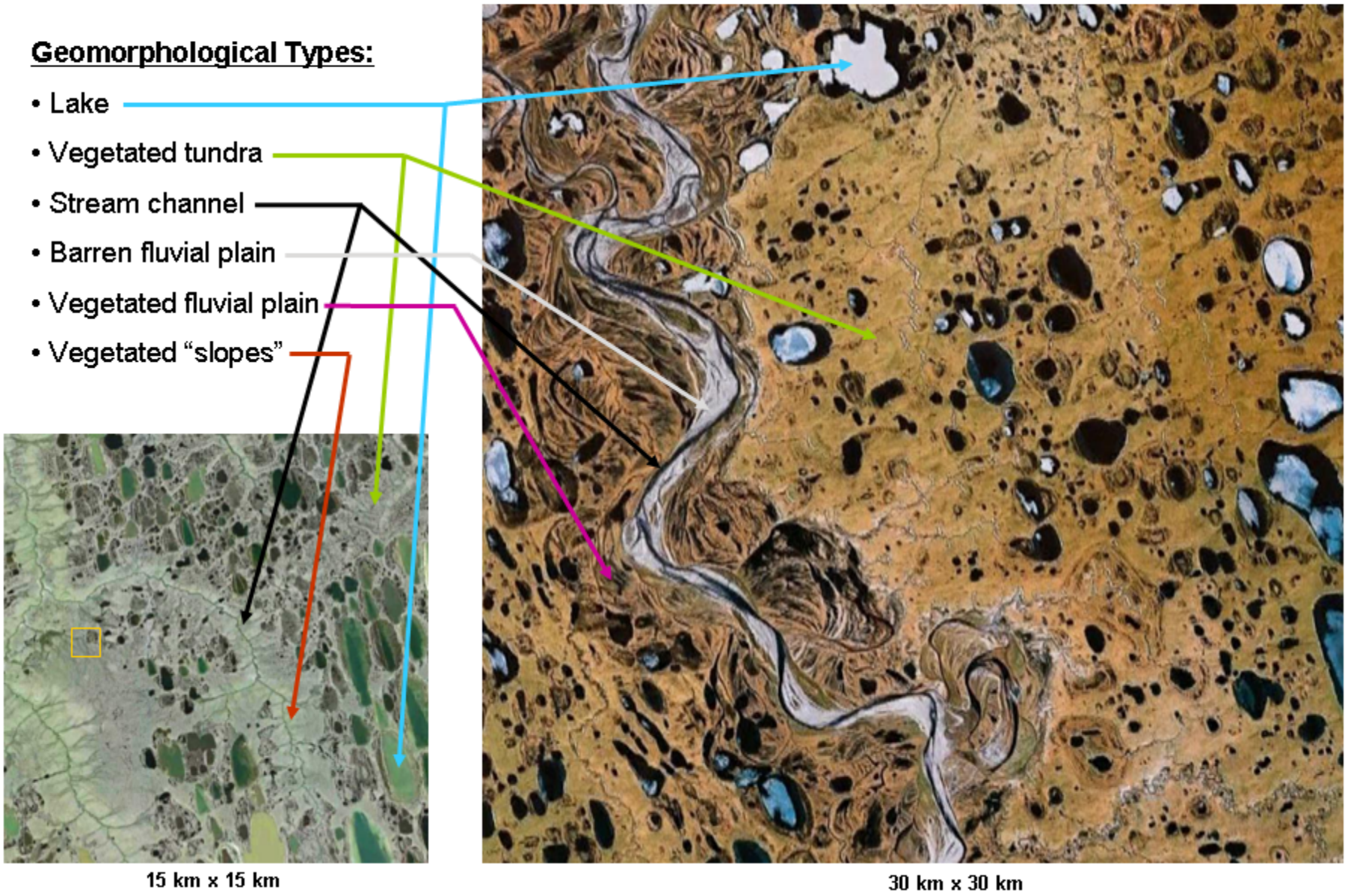
Example 3-D landscape model grids

Barrow Environmental Observatory (BEO)




Grid A
Grid D
Grid C
Grid B
N
0 15 30 60 90 120
Meters

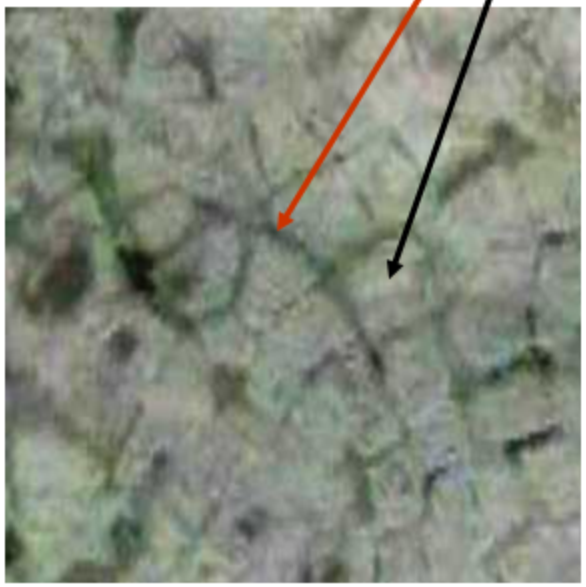
Sub-grid representation of geomorphologically distinct landscape elements



Sub-grid representation of geomorphologically distinct landscape elements

Geomorphological Types:

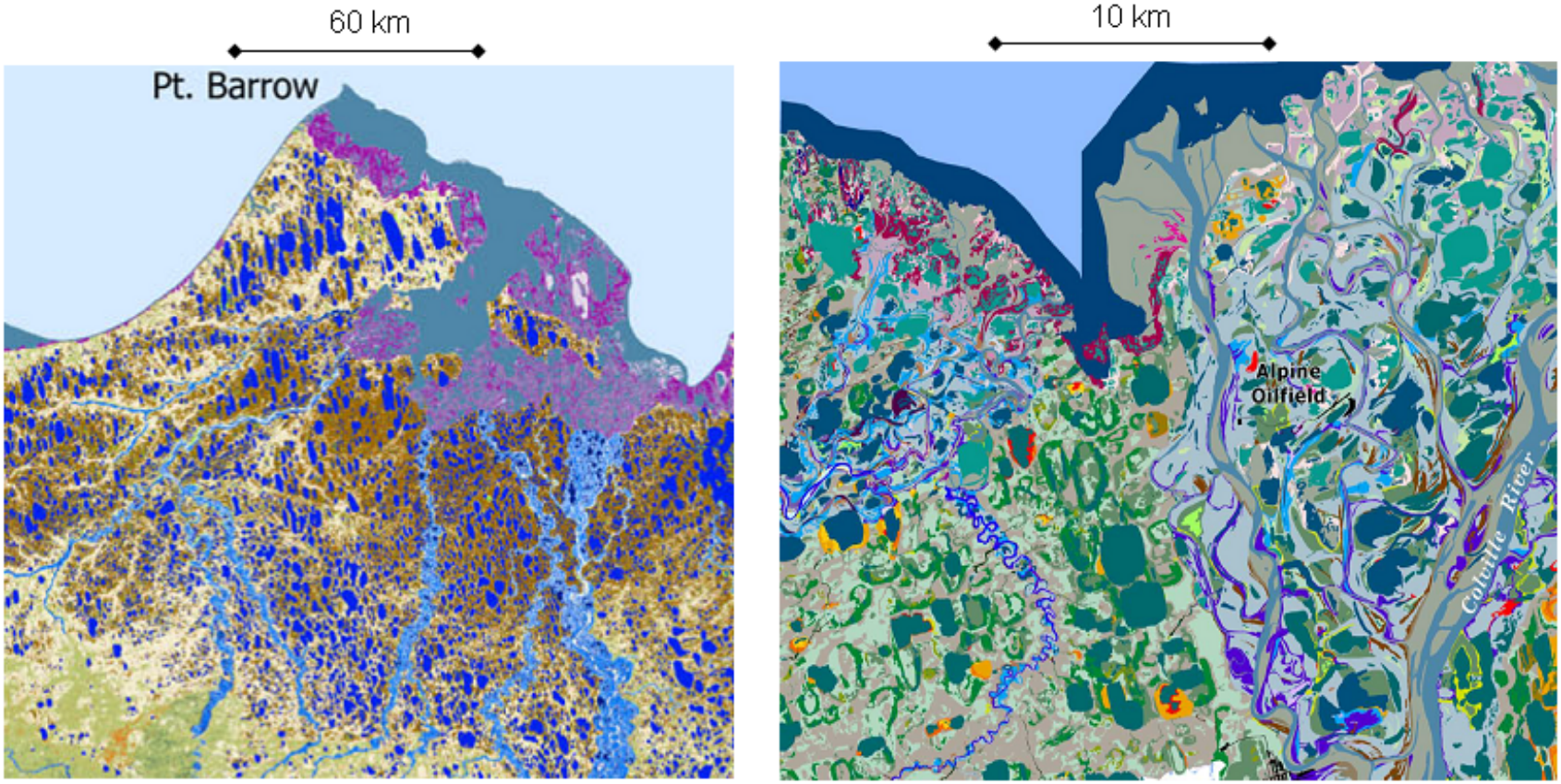
- Lake
- Sunken-center polygon
- Raised-center polygon
- Rim (raised edge)
- Trough (sunken edge)



100 m x 100 m

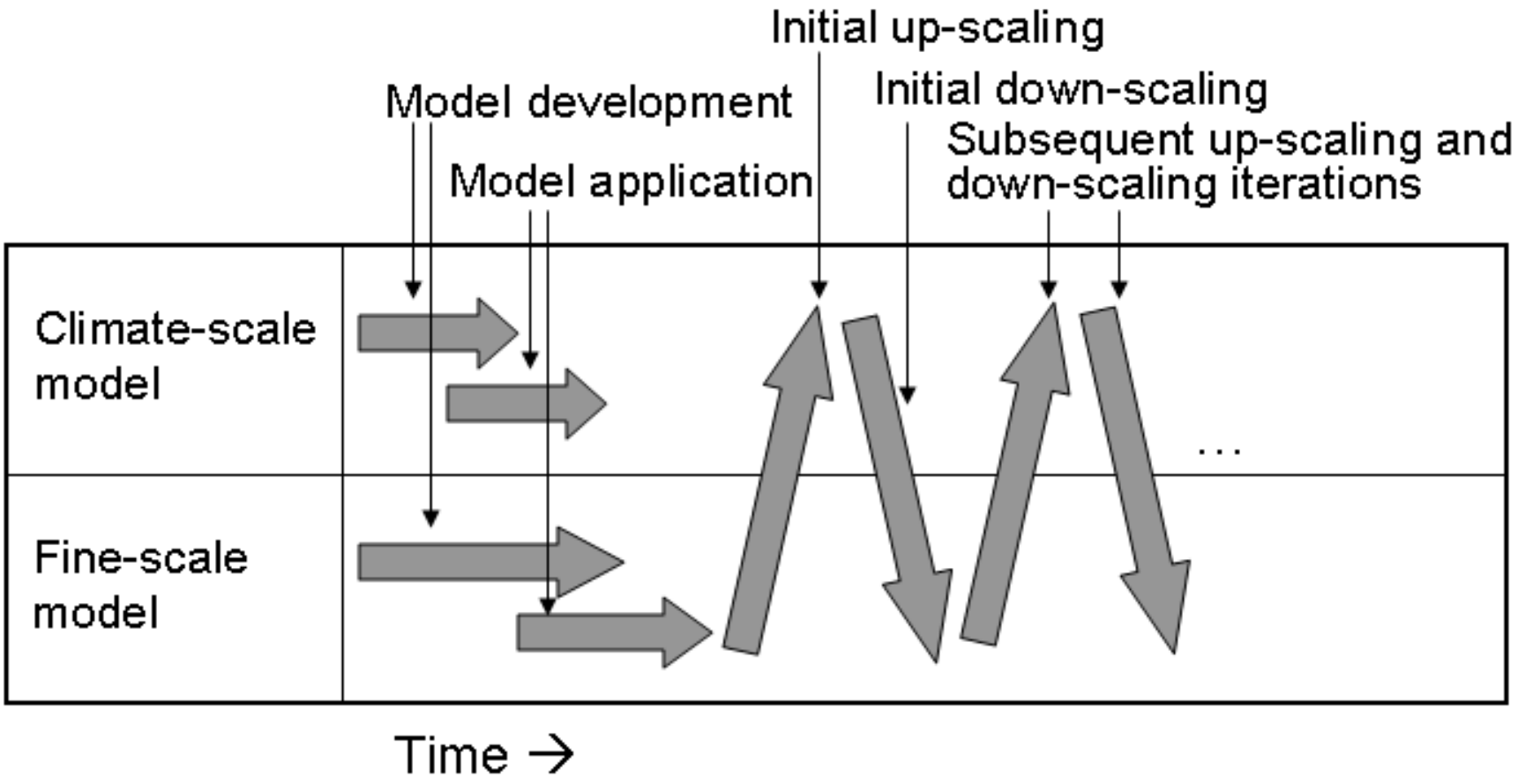
200 m x 200 m

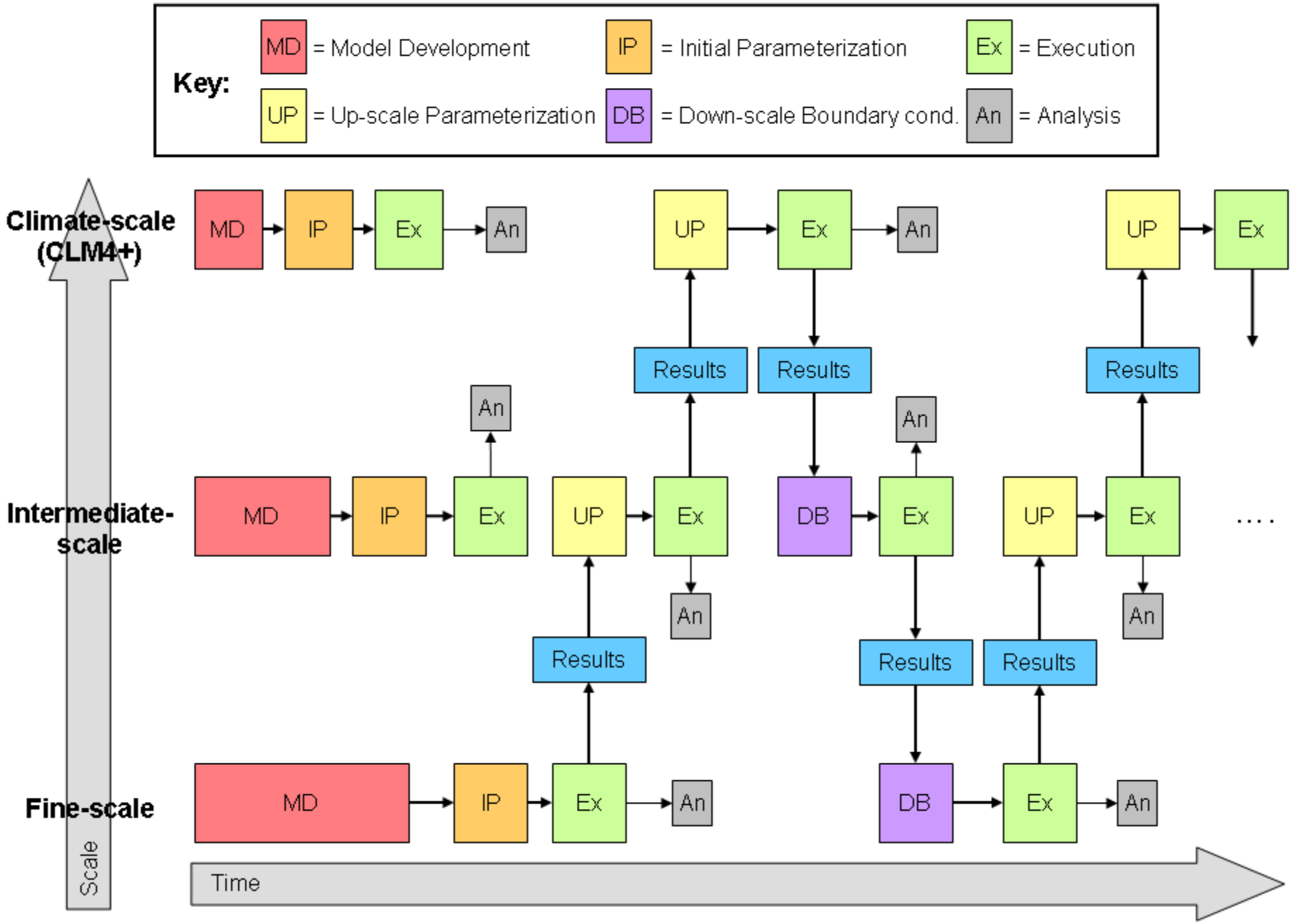
Automated mapping of geomorphological units on Arctic coastal plain



Subsets from two recent remote sensing based efforts to map geomorphological units across the Alaskan North Slope tundra region. Left: from Jorgensen and Heiner, 2004. Right: from Jorgensen et al. 2005.

Up-scaling and down-scaling to achieve improved climate prediction




Key:
MD = Model Development
IP = Initial Parameterization
Ex = Execution
UP = Up-scale Parameterization
DB = Down-scale Boundary cond.
An = Analysis
Climate-scale (CLM4+)
Intermediate-scale
Fine-scale
Scale
Time
Results
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